GLAST Calorimeter
Gamma Ray Bursts and Baseline Design
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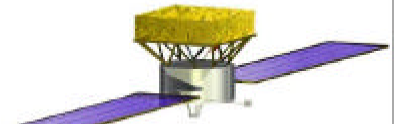
Baseline GRB Capability

- Threshold trigger rates (E > ~2 MeV) will be available with TBS sample timing for lowest energy response to bursts
  - rates only, no spectroscopy
  - currently, have not considered software to support burst detection, but wouldn't be a big problem; what is sensitivity?
    - OSSE Shield rate (NaI) above 1 MeV: ~ 1.5 cm^{-2} s^{-1}
    - compare to GRB flux of ~ 0.05 γ cm^{-2} (E > 1 MeV) for GRB of 1/week size (based on BATSE 1 γ cm^{-2} in 50 - 300 keV band)
    - è GLAST won't trigger - 1.5σ deviation
- Respond to Level 1 Triggers caused by GRB
  - provides spectroscopy to lowest tracker trigger energy (10 MeV?)
  - includes both tracker and calorimeter (> ~ 1 GeV) triggers
- Design Modification Objective - Calorimeter spectroscopy starting near 1 MeV
  - consider enhanced electronics on top layer(s) of calorimeter

Baseline Calorimeter Trigger

- Calorimeter responds to L1 Trigger signal from DAQ
  - All CsI detectors are digitized and transmitted to DAQ
  - Current design indicates dead time of ~ 17 μsec/L1T
  - L1 Trigger rate: 1400 Hz, orbit ave (~ x4 for peak rate)
- Calorimeter provides input of "cal only" trigger signal to DAQ trigger logic
  - GSFC simulations, suggest ≥ 2 crystals (in any tower) with > 100 MeV
    - ~90% efficiency for finding 1 GeV photons, 70% efficiency at rejecting CRs
  - L1 trigger rate: 250 Hz, orbit ave (~150 Hz not triggered by tracker also)
  - Cal only trigger derived from discriminator on fast shape signals (0.5 μs peaking) in low energy channel.
  - Calorimeter tower controller detects number of crystals signaling and creates signal to DAQ. Trigger input delay must be < 1 μsec .
- Ground Test Mode - calorimeter triggers from "or" of low energy range lower level discriminators to capture muon tracks in calorimeter



Modifications for GRB Support
Top 1, 2 Layers of Calorimeter

- Trigger on "or" of low range threshold discriminators (LLD), as in muon test mode, could provide GRB trigger for depositions > ~ 2 MeV
  - Support this on top layer (two layers?) only.
- If the entire calorimeter of a tower is readout, this requires essentially no changes to the hardware, but …
  - Does the DAQ know what to do with the data?
  - Simulations show that single crystal readout gets most of the energy.
  - What do we do about deadtime? Each calorimeter would have its own deadtime and might be busy digitizing GRB/bkg photon when L1T occurs.
- Consider:
  - estimated noise is 2000 e^- (0.4 MeV),
  - nominal threshold is 2 MeV (5σ)
  - views the sky thru 2 mm of Tungsten

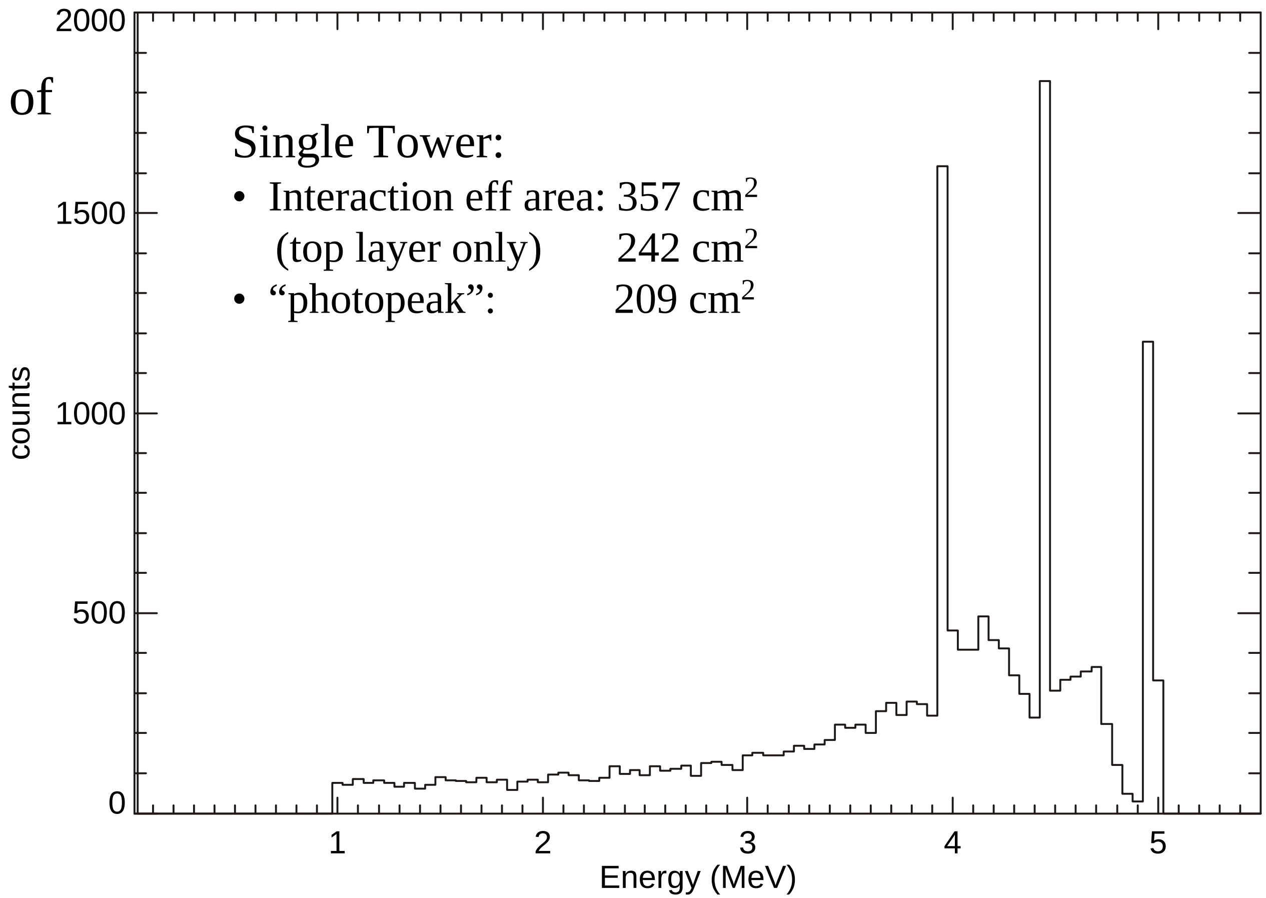
Monte Carlo - Top 2 Layers
5 MeV Photons

Response below 2 mm of Tungsten

32 cm Tower Config

Normal Incidence
10 keV "Resolution"

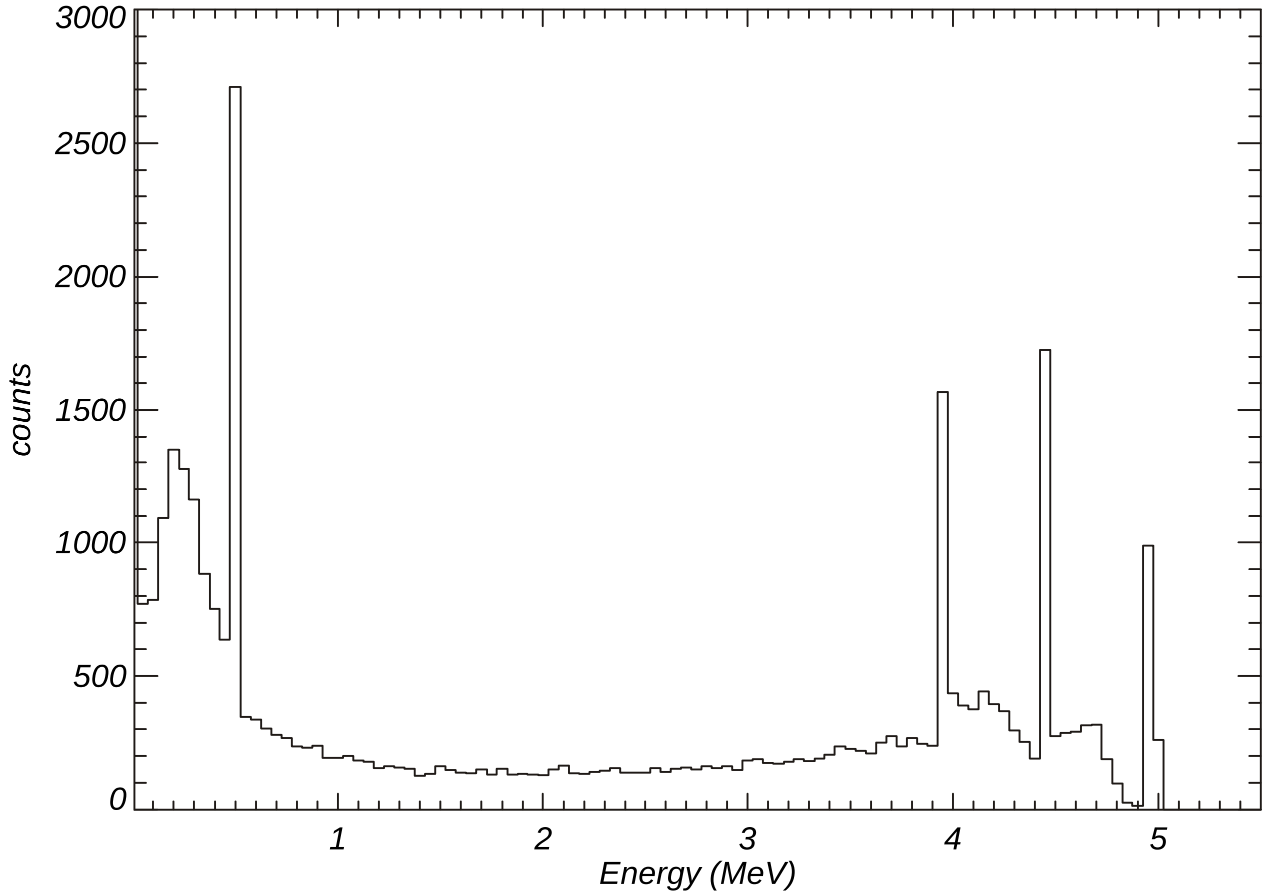
Total energy per event



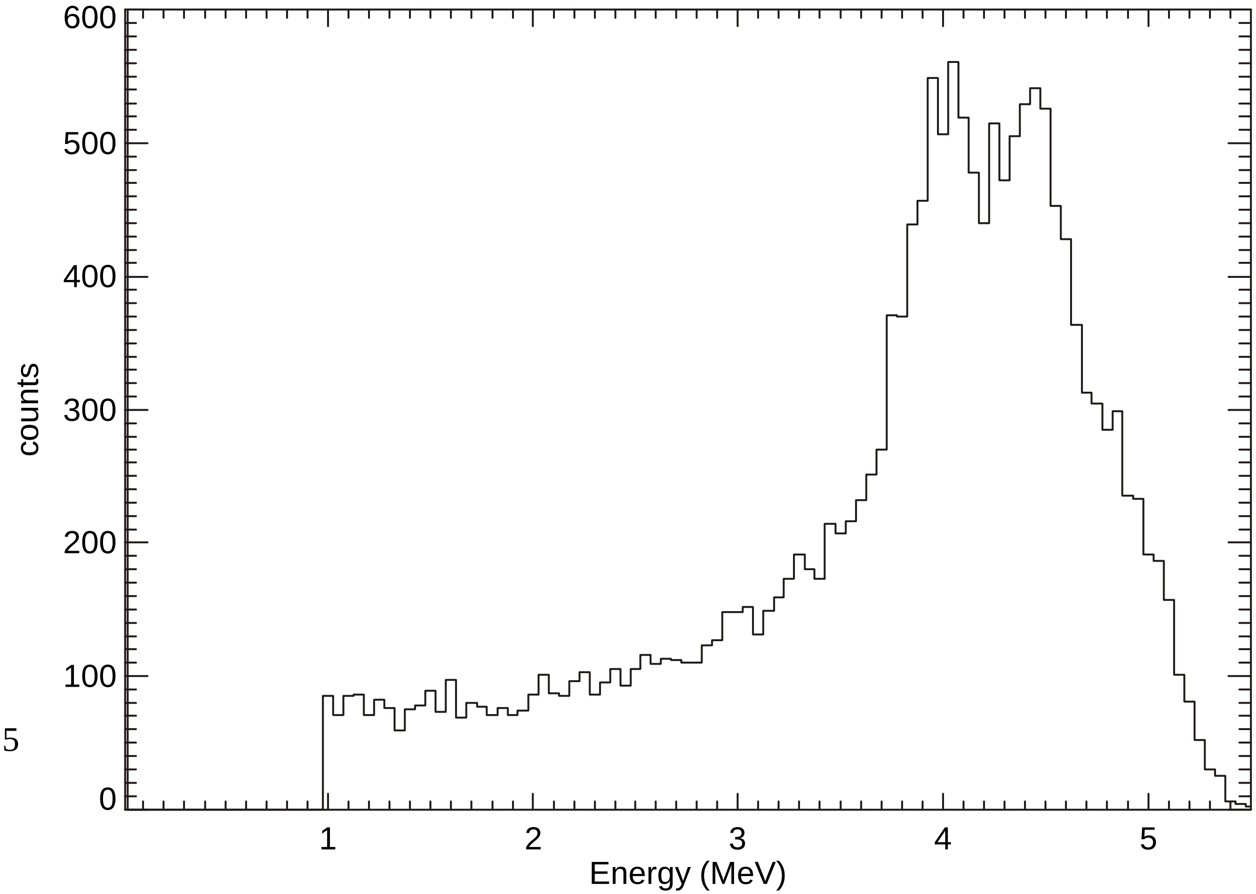
Single Crystal Response
5 MeV Photons

Normal Incidence
10 keV "Resolution"

Sum of single crystal
histograms - 2 layers



Expected Energy Resolution
5 MeV Photons



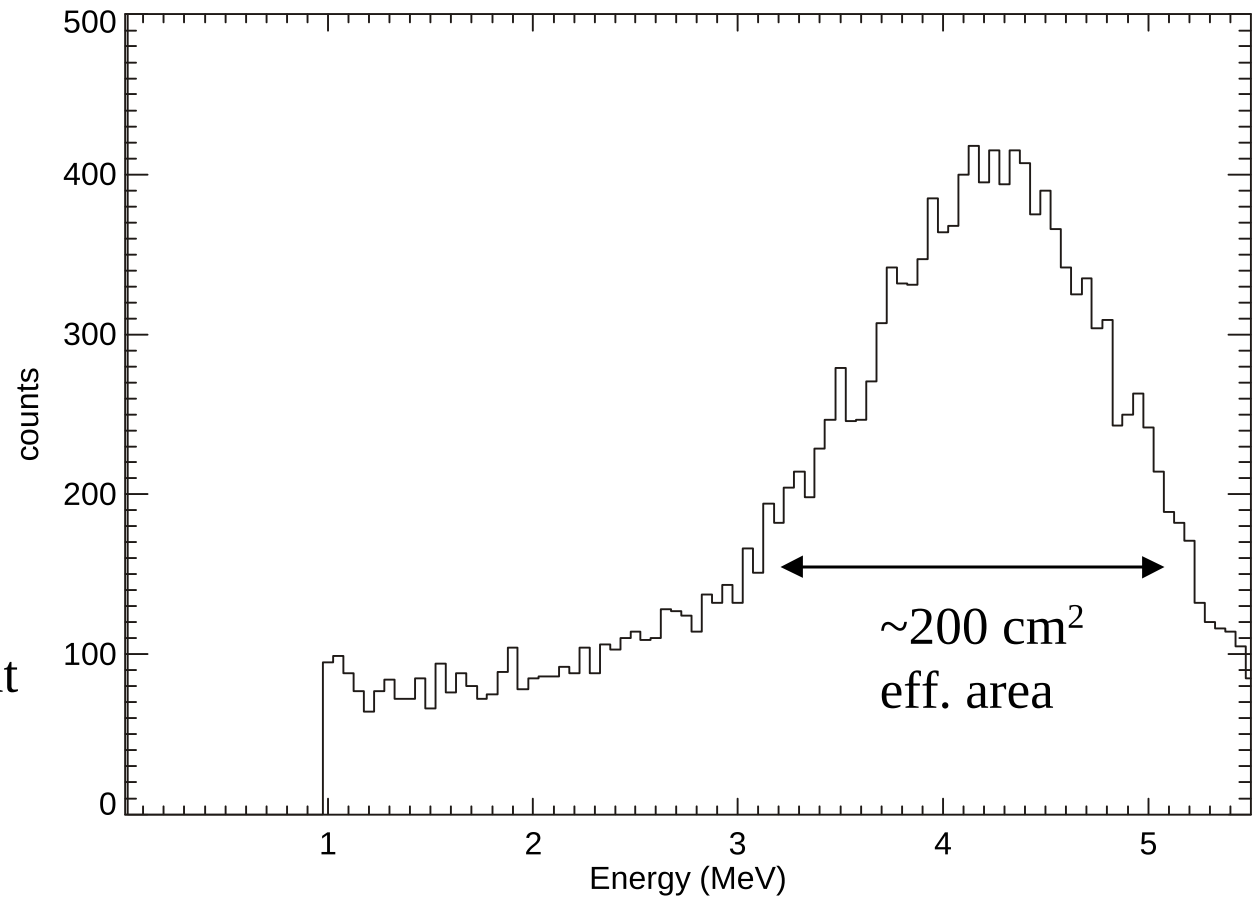
Energy resolution
10% / (E/2.8 MeV) $^{0.5}$

Energy Resol + Electronic Noise
5 MeV Photons

Energy resolution:
$10\% / (E/2.8)^{0.5}$

Noise Estimate:
2000 e^- (0.4 MeV)

2.5 MeV band near full energy loss represents equivalent effective area of ~200 cm^2/tower or ~20% efficiency

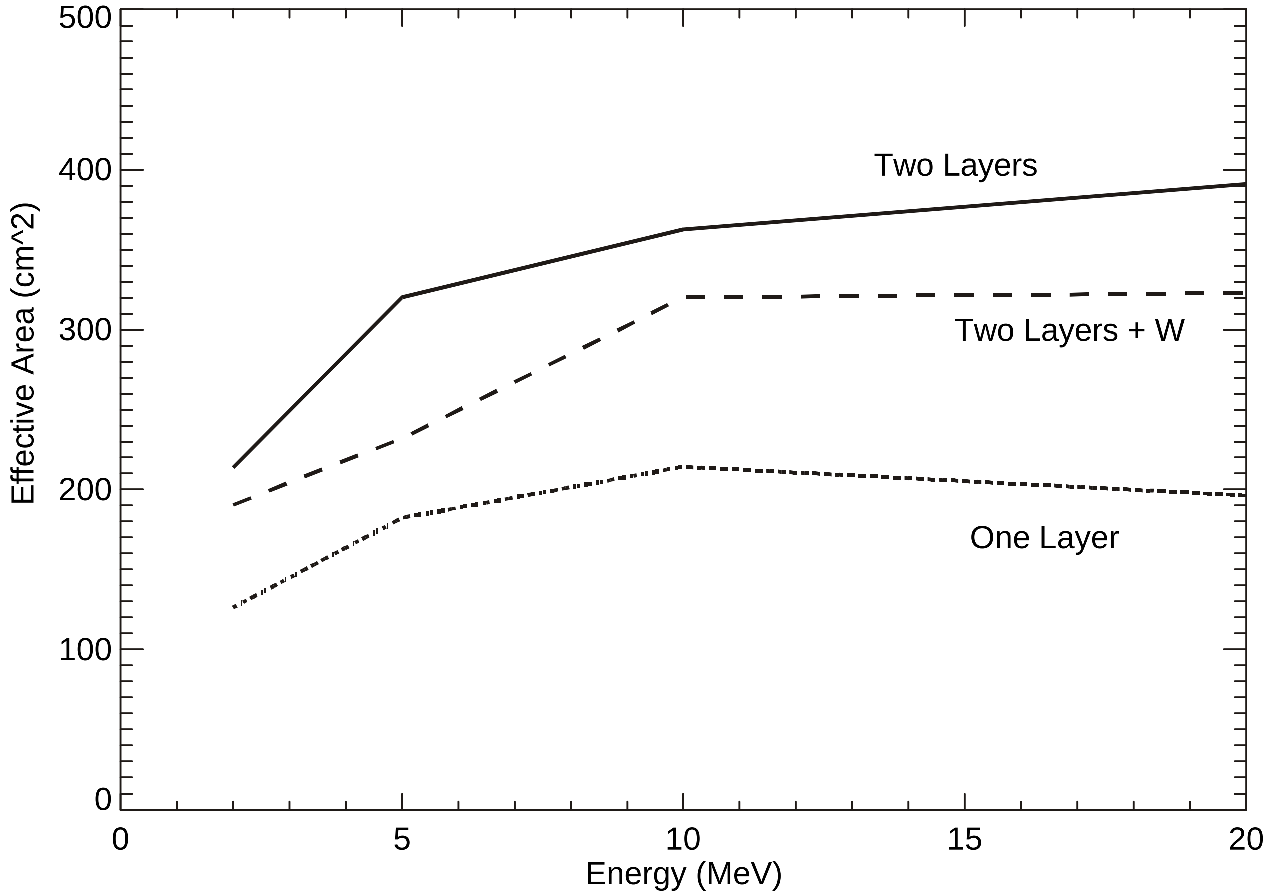


Single Tower (32 cm) Effective Area

Normal Incidence

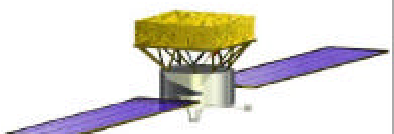
2 mm Tungsten

Based on events with > 60% full energy loss

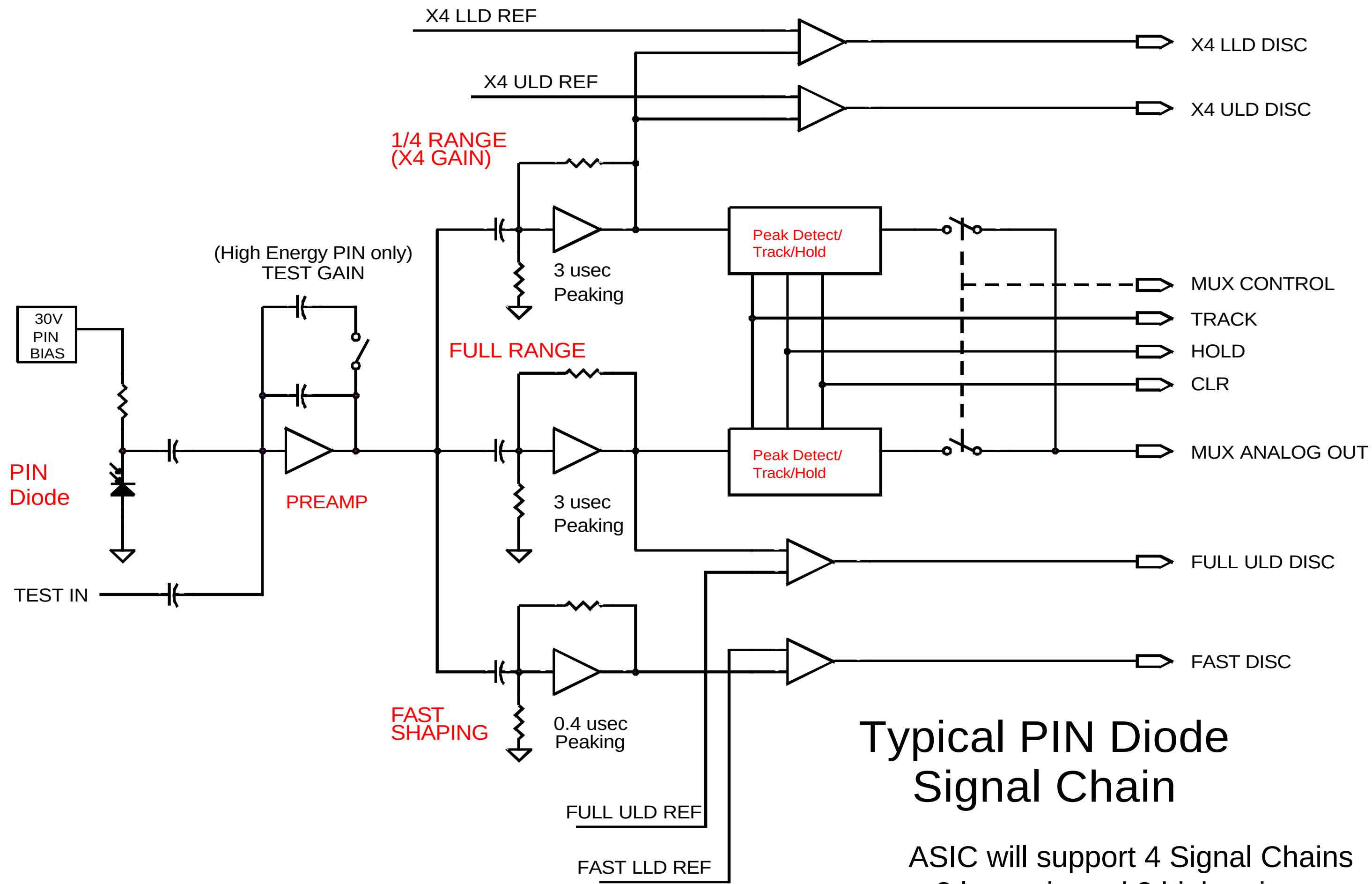


Calorimeter Electronics Requirements

Number of Channels:	160 / tower (80 CsI blocks, both ends)
Dynamic Range:	3 x 10^5
Noise goal:	0.4 MeV (2×10^3 e^-)
A to D Range:	~2 MeV – 100 GeV
Electronic Resolution:	~ 1% (except at threshold)
Trigger Rate: (GLAST)	1200 Hz (Trkr, orbit ave)
	+250 Hz (Cal, orbit ave) 4000 Hz (peak)
Self trigger delay:	< 1 μsec
Trigger Dead time:	10 μsec (goal)
Power:	5 watts / tower
	~ 62 mW / CsI block



Prototype ASIC PIN Signal Chain



Typical PIN Diode Signal Chain

ASIC will support 4 Signal Chains
- 2 low gain and 2 high gain.

GLAST Calorimeter ASIC Baseline Functionality

Each ASIC supports 2 CsI Detectors - 2 high energy and 2 low energy PINs.

- **Low Energy PIN channel functionality (1 - 800 MeV)**
  - PIN area ~96 mm^2, ~0.8 fC/MeV
  - Net gain ~ 5.5 mV/fC
  - PreAmp input C ~ 80 pf
  - Noise goal: <2000 e$^-$ (0.4 MeV)
  - $\times$4 Shaper, ~3.5 μsec peaking
    - Programmable lower level discriminator (LLD)
    - Fixed upper level discriminator
    - Peak detect and hold
  - Full Range Shaper, ~3.5 μsec peaking
    - Fixed upper level discriminator
    - Peak detect and hold
  - Fast Shaper, ~0.5 μsec peaking
    - Range: ~ 50 - 800 MeV
    - Programmable lower level discriminator (FLLD)

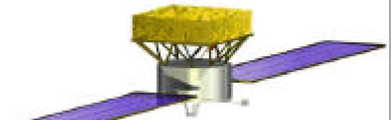
GLAST Calorimeter ASIC Baseline Functionality (cont)

❑ High Energy PIN channel functionality (800 MeV - 100 GeV)

- Pin area 24 mm^2, ~0.2 fC/MeV
- Net gain ~ 175 μV/fC
- PreAmp input C ~ 30 pf
- Noise goal: < 10000 e$^-$ (8 MeV)
- ×8 Shaper, ~3.5 μsec peaking
  - Programmable lower level discriminator (LLD)
  - Fixed upper level discriminator
  - Peak detect and hold
- Full Range Shaper, ~3.5 μsec peaking
  - Fixed upper level discriminator
  - Peak detect and hold
- Fast Shaper, ~0.5 μsec peaking
  - Energy Range: 500 MeV - 100 GeV
  - Programmable lower level discriminator (FLLD)

Calorimeter ASIC
Gain Scale Summary

	High Gain X4	High Gain Full	Low Gain X8	Low Gain Full
Max Energy	200 MeV	800 MeV	12.8 GeV	102 GeV
Chan Width	0.049 MeV	0.19 MeV	3.1 MeV	25 MeV
Threshold	2 MeV	80 MeV	300 MeV	12 GeV
Noise Estimate (Simulation)	1500 e^- rms (0.30 MeV)	1200 e^- rms (0.24 MeV)	Need Simulation	Need Simulation
Quantization Error @ Thresh	2%	0.1%	1%	0.2%
Chan # of 1 MIP	254/4096	63/4096	3/4096	0
Chan # of ^{12}C	**	2294/4096	143/4096	17/4096



Expected
Calorimeter Event Rate

- Calorimeter Event Rate dominated by Galactic Cosmic Rays
- Other important components
  - Trapped protons in earth's magnetic field
  - Earth albedo particles (protons & neutrons)
  - Earth albedo gamma rays
- Net Rate for total GLAST is 4,000 s^{-1} (orbit average), 16,000 s^{-1} (max)
  - This is essentially all GCRs
- From Monte Carlo (GLASTSIM) simulations
  - Cosmic ray crystal multiplicity is mean ~ 60, max ~ 300
  - Gamma ray crystal multiplicity is mean ~ 70, max ~160.
- Orbit Average Threshold rate is 4000 $s^{-1} \times 60$ mult / 2000 crystals = 120 s^{-1}
- Peak Threshold rate is 16,000 $s^{-1} \times 60$ mult / 2000 crystals = 480 s^{-1}